TECHNICAL PAPER

STANDARDIZED UXO DEMONSTRATION SITES

TETRA TECH FOSTER WHEELER, INC. EM-61 MKII MAN-PORTABLE SENSOR SYSTEM - *BLIND GRID SCORING RECORD NO. 159*

The EM-61 Man-Portable Sensor System was demonstrated by Tetra Tech Foster Wheeler, Inc. at Aberdeen Proving Ground, Maryland.

The EM-61 MKII Man-Portable Sensor System is an electromagnetic induction system that was demonstrated as a man-portable platform by Tetra Tech Foster Wheeler, Inc. at the Aberdeen Proving Ground Blind Grid Area. This technical paper contains the results of that demonstration. This is a reference document only and does not serve as an endorsement of the demonstrator's product by the US Army or the Standardized UXO Technology Sites Program.

The Geonics EM-61 MKII TDEM geophysical sensor, Arc Second Constellation™ (CST) and Leica Series 1100 Robotic Total Station (RTS) laser positioning systems are proposed for Aberdeen Proving Ground, Maryland.

The EM-61 MKII uses time domain technology to facilitate the detection and discrimination of metallic objects. Two coils, 100 by 100 cm, are oriented in a horizontal coplanar fashion and separated by a vertical distance of 40 cm. The system is utilized either on nonmagnetic wheels or as a man-portable unit (terrain-dependent) with the lower coil 40 cm above the ground surface. In general, a transmit pulse of unipolar rectangular current (25 percent duty) of very short duration is applied to the lower coil. This primary current creates a primary magnetic field that induces eddy currents in nearby metal objects. The current flowing in the metal object creates a secondary magnetic field that is detected by both the lower and upper coils. The transmitter pulse frequency is 75 Hertz (Hz), the pulse duration is 3.3 milliseconds, the peak power output is 50 watts, and the average power is 25 watts. Both coils possess zero decibels of gain.

The secondary magnetic field created by metal objects is sampled by the EM-61 MKII electronics, which reside in the backpack, at times of 216 microseconds (μs), 366 μs, 660 μs on the bottom coil and 660 μs on the top coil after the turn-off of the transmit pulse. Digital data for these four individual time gates are integrated and recorded to a Juniper Allegro field computer at a rate of 12 Hz. The individual time gate data are converted into units of millivolts (mV), normalized, and gain is applied to each time gate by the EM-61 MK2A software v1.22 on the Juniper Allegro field computer. Normalization and gain parameters reside in the EM-61 MKII manual, Appendix B.

Safety hazards for the EM-61 MKII equipment include electromagnetic radiation. The electromagnetic field of the system could potentially detonate some types of specialized ordnance. The hazards of electromagnetic radiation to ordnance (HERO) distance for the EM-61 MKII is 20 cm. The Army Corps of Engineers recommends a ground clearance of at least 40 cm when electrically fuzed ordnance is present.

The CST consists of four laser transmitters and a field computer for logging the position data via wireless modem. Four Trimble Spectra Precision LS920 Laser Transmitters are positioned in a diamond or square geometry over 1/2 to 1 acre, depending upon the tree density. The transmitters are leveled, and an automatic routine calculates the relative x-y-z plane between the transmitters to a tolerance of 1 inch or less. A laser detector wand (i.e., receiver) is centered over the EM-61 MKII coils on a Tetra Tech Foster Wheeler (TtFW)-designed fiberglass doghouse. The detector wand receives the laser pulses from the four transmitters simultaneously, and computes a position based on the known position of the laser transmitters.

Only two of the laser transmitters are necessary to compute a reliable position to a relative accuracy of approximately 1 inch. The position data are updated at 2 to 3 Hz and sent via wireless modem to the field computer for storage.

The Leica Series 1100 RTS consists of a laser-based total station survey instrument (transmitter), prism (receiver), and RCS 100 remote control. The transmitter is positioned over a ground position point of known location, and an x-y-z Cartesian coordinate system is defined by occupying an additional known ground position with the receiver prism. The receiver prism is mounted on a TtFW doghouse

centered over the EM-61 MKII coils, and the RTS automatically tracks the prism at distances of several thousand feet to an accuracy of approximately 1 inch. Position data for the receiver prism are updated at a rate of 3 to 4 Hz and stored on a Personal Computer Memory Card International Association (PCMCIA) card located on the robotic total station.

EM-61 and CST Positioning System: EM-61 configured as two-man tethered carry (proposed for use in dense woods and rougher surface areas at APG). Illustration shows light-moderate wooded areas at Fort McClellan, Alabama, where TtFW geophysicists have perfected the use of the CST laser-based positioning system.

In the densely wooded area, the CST laser-based positioning system will be integrated with the EM-61 MKII geophysical sensor and used as a two-man tethered system, or in areas where the surface terrain is judged to be smooth, as a one-man cart. The four transmitters will be organized in a diamond or square geometry over an area of 1/2 to 1 acre in size, depending on the area-specific vegetation density. At least two of the laser transmitter locations will be surveyed with the RTS instrument (located at a known control point) in order to position the data in the requested coordinate system.

The RTS laser-based system was used in conjunction with the EM-61 MKII in the areas outside of the dense woods. The survey area will be divided into two-acre plots (grids), and wood survey lathe will be positioned at predefined grid corners using the RTS.

For this demonstration, a transect spacing of no more than 2 to 2.5 feet is required when using the proposed geophysical sensor to detect and discriminate objects as small as 20-mm projectiles.

Several fiberglass tape measures are laid out perpendicular to the direction of the data acquisition transects at intervals of approximately 50 to 100 feet. Specially modified traffic cones are positioned along the intended transect at the measuring tape locations; the data acquisition crew uses these cones as waypoints. When the crew reaches a waypoint, the sensor operator moves the cone sideways to the next intended transect (2 to 2.5 ft to the side), and continues navigating to the next waypoint (cone) along the current transect. The acquisition crew proceeds a minimum of 10 feet outside of the intended survey area, reverses direction, and proceeds along the next intended transect. When encountering an obstacle, the sensor operator pauses for 1 second, steps around the obstacle, and pauses for an additional second. In this manner, the highest quality spatial data is obtained around obstacles. In areas where rough terrain is present (moguls, slopes, etc.) pin flags may be employed rather than traffic cones, at intervals of 25 feet. A Juniper Allegro ruggedized data collector records the EM-61 MKII data at 12 Hz. At a normal acquisition speed of 3 feet per second, samples along each acquisition transect are produced at intervals of approximately 3 to 4 inches. Geonics software DAT61MK2 v1.30 is used to convert the EM-61 MKII data to units of mV with a corresponding time stamp for each record.

The CST positioning information is recorded via wireless modem to a binary file at 2 to 3 Hz to a field computer, along with a corresponding time stamp for each recorded position. The positioning and EM-61 MKII signal data are merged with the software Vulcproc v1.5 developed by TtFW.

Position data are collected with the RTS at a rate of 3 to 4 Hz and stored, along with a time stamp, on a PCMCIA card in the RTS. The positioning and EM-61 MKII signal data are merged with the software RTSproc v2.2 developed by TtFW.

The data are leveled (background subtraction as determined by mode of data) during processing and are output as an ASCII file (x, y, z1, z2, z3, z4, z5) that contains the state planar coordinates of each measurement location in feet, EM-61 MKII signal intensity for each time gate in millivolts, and a quality identifier for each recorded position (number 1 to 6, based on standard deviation).

The raw data for all three instruments (EM-61, CTS, RTS) is uploaded to a PCMCIA card and transferred to the in-field processing computer and backed up on CD-ROM.

Performance Summary

Results for the blind grid test, broken out by size, depth, and nonstandard ordnance, are presented in the table below. Results by size and depth include both standard and nonstandard ordnance. The results by size show how well the demonstrator did at detecting/ discriminating ordnance of a certain caliber range. The results are relative to the number of ordnances emplaced. Depth is measured from the geometric center of the anomaly to the ground surface.

The response stage results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the discrimination stage are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90-percent confidence limit on probability of detection and probability of false positive was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

Summary of Blind Grid Results for EM-61 MKII

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.95	0.90	0.95	0.95	0.95	0.80	1.00	0.90	0.70
P_d Low 90% Conf	0.88	0.85	0.84	0.88	0.61	0.55	0.95	0.80	0.45
P_fa	0.80	-	-	-	-	-	0.80	0.80	1.00
P_fa Low 90% Conf	0.75	-	-	-	-	-	0.69	0.71	0.63
P_{fa}	0.10	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.75	0.80	0.70	0.85	0.65	0.70	0.90	0.80	0.10
P_d Low 90% Conf	0.69	0.71	0.56	0.76	0.51	0.45	0.79	0.68	0.01
P_fa	0.65	-	-	-	-	-	0.60	0.70	1.00
P_fa Low 90% Conf	0.59	-	-	-	-	-	0.49	0.58	0.63
P_{fa}	0.05	-	-	-	-	-	-	-	-

Response Stage Noise Level: 0.04
Recommended Discrimination Stage Threshold: 1.00

Note: *The response stage noise level and recommended discrimination stage threshold values are provided by the demonstrator.*